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REVIEW

Do Vascular Surgery Patients Need a Cardiology Work-up? A Review of Pre-operative Cardiac Clearance Guidelines in Vascular Surgery

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Objectives: to outline the appropriate pre-operative cardiac work-up for patients who are scheduled for major peripheral vascular surgery.

Design: review of the literature.

Materials and Methods: a review of the literature focusing on studies that have correlated the pre-operative cardiac work-up patients receive to the cardiac morbidity and mortality following vascular surgery. Only studies with level A evidence were included.

Results: peri-operative beta blockade has been shown to decrease cardiac complications after vascular surgery in all risk groups. Non-invasive cardiac testing is only necessary for patients in the intermediate/high risk group. Coronary revascularization should only be considered after a positive non-invasive cardiac test.

Conclusions: patients must be risk stratified pre-operatively based on history and physical examination. Low risk patients should receive peri-operative beta blockade only with no further non-invasive testing. On the other hand, intermediate and high risk patients should undergo non-invasive cardiac testing before going to the operating room.

Key Words: Risk factors; Risk assessment; Peri-operative care; Cardiovascular surgical procedures.

Introduction

As the U.S. population ages the number of vascular surgery procedures continues to rise. Myocardial infarction (MI) and congestive heart failure remain the most common cause of death in the post-operative patient.¹ Numerous reports have also confirmed that patients undergoing vascular reconstruction have an elevated cardiac risk.^{2–4} A team approach emphasizing communication between the patient, primary care physician, anesthesiologist, and surgeon is required for successful peri-operative evaluation and management of patients undergoing surgery.

When considering a patient for surgery a careful pre-operative clinical evaluation is essential to reduce post-operative cardiac complications. The history and physical examination should focus on identifying

potentially serious cardiac disorders such as prior MI, angina pectoris, and congestive heart failure. Significant comorbid diseases should also be identified, such as, diabetes mellitus, renal insufficiency, and chronic pulmonary disease. A pre-operative electrocardiogram (ECG) is helpful to recognize arrhythmias and signs of old (Q waves) or current (ST segment changes) cardiac ischemia. The physician should assess the patient's functional capacity. The Duke Activity Status Index (Table 1),³⁹ and other activity scales provide the surgeon with a set of questions to determine a patient's functional capacity. These questions focus on everyday activities such as eating, dressing, walking around the house, climbing a flight of stairs, running a short distance and swimming. Each of these activities is given a specific score. The Duke Activity Status Index was developed to assess functional capacity in a way that correlates with oxygen uptake by weighting questions according to known metabolic cost of each activity.

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Table 1. Duke activity status index.

Can you . . .	Weight
1. Take care of yourself that is, eating, dressing, bathing, and using the toilet?	2.75
2. Walk indoors, such as around your house?	1.75
3. Walk a block or tow on level ground?	2.75
4. Climb a flight of stairs or walk up a hill?	5.50
5. Run a short distance?	8.00
6. Do light work around the house like dusting or washing dishes?	2.70
7. Do moderate work around the house like vacuuming, sweeping floors, carrying in groceries?	3.50
8. Do heavy work around the house like scrubbing floors, or lifting or moving heavy furniture?	8.00
9. Do yard work like raking leaves weeding or pushing a power mower?	4.50
10. Have sexual relations?	5.25
11. Participate in moderate recreational activities, like golf, bowling, dancing, double tennis, or throwing baseball or football?	6.00
12. Participate in strenuous sports like swimming, singles tennis, football, and basketball or skiing?	7.50

Each question can be answered one of four ways, with each answer having a weighted score:

- A. Yes, with no difficulty = 1
- B. Yes, with some difficulty = 2
- C. No, I can't do this = 3
- D. Don't do this for other reasons = 4

Total score is then calculated.

Risk Stratification

During the history and physical examination it is not only important to identify heart disease, but it is essential to gauge disease severity, stability, and prior treatment. Once the patient's risk factors are identified, it is essential to determine whether the patient is at high, intermediate, or low risk for peri-operative cardiac complications. The American College of Cardiology (ACC) and the American Heart Association (AHA) published guidelines for risk stratification of patients undergoing non-cardiac surgery (Table 2).⁵ The goal of risk stratification is to reduce overall morbidity and mortality. Factors that help determine cardiac risk include functional capacity, age, comorbid disease (i.e. diabetes mellitus, renal insufficiency, chronic pulmonary disease) and high risk surgery. For patients who have undergone coronary revascularization in the past 5 years, and their clinical status has remained stable without recurrent symptoms/signs of ischemia, further cardiac testing is not necessary. If a patient had an adequate coronary evaluation within the last two years and the findings were favorable, it is usually not necessary to repeat testing unless there are new symptoms of coronary ischemia since the previous evaluation.

Table 2. Risk stratification.

Low risk
Advanced age
Abnormal ECG
Rhythm other than sinus
Low functional capacity
History of stroke
Uncontrolled hypertension
Intermediate risk
Prior MI
Diabetes mellitus
Compensated or prior CHF
Mild angina pectoris
High risk
Recent MI
Unstable or severe angina
Decompensated CHF
Significant arrhythmia
High grade AV block
Symptomatic arrhythmias in the presence of underlying heart disease
Supraventricular arrhythmias with uncontrolled ventricular rate
Severe valvular disease

The information gathered from the history and physical will help risk stratify the patient as either low, intermediate or high risk for a peri-operative ischemic event. Consideration for further diagnostic testing is based on what risk category the patient is placed. In the case of patients with one or more risk factors, the most important issue to consider is how the results of various cardiac tests will influence decision making and management.

Non-invasive Pre-operative Cardiac Testing

It is important to recognize which patients are most likely to benefit from pre-operative coronary assessment and treatment. Patients who fall into the low risk category need no further evaluation.⁶ In these low risk patients, the occurrence of myocardial ischemia on stress testing has a low positive predictive value, and may be associated with more false positive than true positive results.²⁵ Numerous studies have shown that low risk patients have an extremely small risk of peri-operative cardiac complications when treated with peri-operative beta blockade only (please refer to the medical therapy section for more details). Therefore, the results of further cardiac testing should not change the management in these patients. Hence, further testing is not cost effective in this group. Patients who are at intermediate or high risk of a peri-operative cardiac complication warrant further testing, only if the finding of stress induced myocardial ischemia, clinically significant ventricular or valvular disease may lead to

coronary revascularization, the initiation of medical therapy to decrease the risk of cardiac complications, or a difference in peri-operative monitoring.

Non-invasive tests are available which assess left ventricular function (radionuclide angiography), cardiac ischemia (exercise or pharmacological stress testing and ambulatory electrocardiographic monitoring), or both (dobutamine stress echocardiography). It is important realize that a non-invasive test may detect a cardiac abnormality, but this by itself does not always predict increased risk. Also, it must be stressed that the results of non-invasive tests are open to interpretation by the physician reviewing the study.⁷⁻⁹

Radionuclide angiography and transthoracic echocardiography are the major methods for assessing left ventricular ejection fraction, but both tests have never been shown to help predict post-operative myocardial infarction and cardiac death.¹⁰⁻¹² Exercise electrocardiography is the least expensive non-invasive test for myocardial ischemia. This test can be performed in the outpatient setting by trained personnel who are under the supervision of a physician. During this test, the physician should be available in case of an emergency. The rate of acute MI or death is about 1 per 2500 tests.³⁷ A large amount of information can be derived from an exercise test, such as, electrocardiographic changes, a patient's symptoms and exercise capacity, and the hemodynamic changes (e.g. heart rate and blood pressure) that occur in response to exercise. The data obtained from exercise electrocardiography can be integrated through the use of the Duke treadmill score,³⁸ which is calculated as follows: duration of exercise in minutes – (5 × the maximal net ST-segment deviation during or after exercise, in millimeters) – (4 × the treadmill angina index). The angina index is assigned a value of 0 if angina is absent during exercise, 1 if typical angina occurs during exercise, and 2 if angina is the reason the patient stopped exercising. Exercise electrocardiography has a sensitivity of 68% and specificity of 77% for the detection of coronary artery disease.^{13,14} However, those patients who are not at high risk for extensive coronary disease, the sensitivity of exercise electrocardiography may be as low as 45%.¹⁵

Stress single-photon-emission-computed tomography (SPECT) uses radioactively labeled tracers (e.g. thallium 201 or technetium 99) to assess myocardial perfusion and viability. The uptake of these agents by myocardial cells depends on both the perfusion and viability of that region of myocardium. The initial distribution of these tracers is proportional to myocardial blood flow, however the redistribution images, which are taken 3–4 h later, reflect myocardial viability and are unrelated to flow. A myocardial defect on an

initial scan that resolves on a delayed scan is an indication that the myocardium is viable. A defect that is seen on both initial and delayed images suggests a region of myocardium that has died, presumably secondary to a MI. Ischemia can be triggered by physical exercise or pharmacological agents (e.g. dobutamine, adenosine or dipyridamole). These three agents are useful in patients who are unable to perform physical exercise.¹⁶ Dobutamine is a positive inotropic agent that provokes ischemia by increasing myocardial work, however adenosine and dipyridamole are vasodilators that unmask coronary stenoses by increasing flow in coronary arteries that are not diseased. SPECT has higher sensitivity 88%, and similar specificity for the detection of coronary artery disease when compared to exercise electrocardiography.^{13,16}

A final mode of non-invasive testing is stress echocardiography. Myocardial stress can be triggered by exercise or pharmacological agents to trigger ischemia.¹⁷ Echocardiographic images obtained at rest and during stress are compared, and areas, which develop wall motion abnormalities during stress, are considered positive. In addition, this test provides information on left ventricular and cardiac valve function. The sensitivity is 77% which is slightly lower than SPECT, but still higher than exercise electrocardiography.^{13,16} Exercise echocardiography has a specificity of 88% for coronary artery disease and this is higher than either SPECT or exercise electrocardiography.¹⁸ The function, sensitivity and specificity of the various non-invasive cardiac tests are summarized in Table 3.

Unfortunately, to date no clinical trials have been performed in patients with suspected coronary artery disease comparing patient outcomes randomly assigned to the three non-invasive cardiac tests. The literature consistently shows that SPECT and stress echocardiography provide more information than exercise electrocardiography alone.^{13,16,19} However, even if a test provides more information it does not mean it is the most appropriate test. No single test has been proven to be superior overall. A substantial proportion of patients with peripheral vascular disease (30–70%) cannot attain target heart rates and therefore cannot complete the exercise portion of the test adequately for diagnosis.^{20,21} Obviously, in a patient who does not have the functional capacity to participate in exercise electrocardiography, this test is not an option. Further more, in patients whose ECG is uninterpretable should not undergo exercise electrocardiography. In patients being considered for SPECT vs stress echocardiography the test that is most established and available at a given institution should be used.

Table 3. Functions of non-invasive cardiac tests and the specificity and sensitivity for the detection of coronary artery disease.

Diagnostic test	Function	Specificity %	Sensitivity %
Radionucleotide angiography	Assess LVEF*	N/A	N/A
Transthoracic echocardiography	Assess LVEF and cardiac valves	N/A	N/A
Exercise electrocardiography	Detects CAD** and assesses functional capacity	77	68
SPECT	Detects CAD	77	88
Stress echocardiography	Detects CAD and assesses LVEF and cardiac valves	88	76

* LVEF = left ventricular ejection fraction.

** CAD = coronary artery disease.

Pre-operative Medical Therapy

The ability of beta-blockers to reduce the peri-operative risk of cardiac complications has been extensively documented. The first randomized trial showing the protective effects of peri-operative beta-blockade in high risk patients undergoing non-cardiac surgery used atenolol in 200 high risk patients.²² Atenolol was administered intravenously or orally beginning two days pre-operatively and continuing for seven days post-operatively, and this reduced the incidence of peri- and post-operative myocardial ischemia by 30–50%.²³

Poldermans *et al.*²⁴ performed a randomized multi-center trial assessing the effect of pre-operative beta blockers in high risk patients undergoing vascular surgery (Table 4). A total of 846 patients were enrolled in this study. Of the 846 patients, 173 had positive results on dobutamine echocardiography. Fifty-nine patients were randomly assigned to receive bisoprolol, and 53 to receive standard care without beta blockade. The remaining 61 patients were excluded from the study because they were either already taking beta blockers or they had extensive wall motion abnormalities at either rest or during stress testing. Two patients in the bisoprolol group died of cardiac causes (3.4%), as compared to the standard care group (17%). Non-fatal MI did not occur in the bisoprolol group, but nine patients in the standard care group had a non-fatal MI. Therefore, cardiac death or non-fatal MI occurred in 3.4% of patients in the bisoprolol group compared to 34% in the standard care group. This study demonstrated the beneficial effect of pre-operative beta blockade in high risk patients undergoing vascular surgery.

Recently Boersm *et al.*²⁵ conducted a cohort multi-center study assessing the effects of peri-operative beta blockers in low, intermediate, and high risk patients undergoing major vascular surgery (Table 5). A total of 1351 patients undergoing vascular surgery were enrolled in the study, and 1118 patients met

Table 4. The effect of bisoprolol on peri-operative cardiac complications in high risk patients undergoing vascular surgery.

	No. of patients	Cardiac death %	Non-fatal MI %	Overall cardiac events %	p value	Level of evidence
Bisoprolol	59	3.4	0	3.4	<0.001	A1a
Placebo	53	17	17	34		

Polderman *et al.*²⁴**Table 5. The effect of beta blockers on peri-operative cardiac complications in low and intermediate/high risk patients undergoing vascular surgery.**

	Beta blockers	Placebo	p value	Level of evidence
Low risk patients with cardiac complications	0.8% (2/363)	2.3% (20/855)	<0.001	A1b
Intermediate/high risk patients with cardiac complications	2.0% (1/50)	10.6% (5/47)	<0.001	

Boersm *et al.*²⁵

clinical criteria for low risk to have a peri-operative cardiac complication. In this low risk group, 263 patients receive peri-operative beta blockade and 855 patients did not. Cardiac complications occurred in 0.8% (2/263) of patients receiving beta blockers, compared to 2.3% (20/855) of patients who did not receive beta blockers. Patients in the intermediate or high risk category also benefited from peri-operative beta blockade. In this group, cardiac complications occurred in 2% of patients receiving beta blockers, compared to 10.6% in patients not receiving beta blockade. The study demonstrated the beneficial effect of peri-operative beta blockade in reducing cardiac complications in all patients undergoing vascular surgery irrespective to risk category.

Coronary Revascularization

Unfortunately, there have not been any randomized or controlled trials assessing the benefit of pre-operative

coronary revascularization on vascular patients. The results of several retrospective cohort studies have been published.^{26–28} One of the studies compared the results of pre-operative percutaneous transluminal coronary angioplasty (PTCA) to coronary artery bypass surgery (CABG) in patients undergoing elective abdominal aortic aneurysm repair.²⁷ The authors retrospectively reviewed the records of 2452 patients who had abdominal aortic aneurysm repair. One hundred patients (4.1%) had coronary revascularization (86 patients had CABG and 14 had PTCA) mostly for symptomatic CAD. There were no peri-operative deaths in the coronary revascularization group, compared with 2.9% peri-operative mortality for the entire group. Huber²⁸ conducted a retrospective study on 50 patients who were at high risk for peri-operative cardiac complications (e.g. multivessel disease and abnormal non-invasive studies) who had PTCA before non-cardiac surgery. In the patients who received PTCA the peri-operative MI rate was 5.9% and the mortality rate was 1.9%. There was no control group, therefore whether or not these results differ from what may have been occurred without PTCA is uncertain. Due to the limited data, prophylactic pre-operative PTCA cannot be advocated in trying to reduced peri-operative cardiac complications in patients undergoing major vascular surgery. Until data proving the contrary, the indications of PTCA in the pre-operative vascular patient is the same as those developed by the joint ACC/AHA Task Force outlining the indication for PTCA in the general patient population.²⁹

As is the case with PTCA, there are no randomized controlled clinical trials proving the benefit of prophylactic CABG to lower the peri-operative cardiac risk in patients undergoing major vascular surgery. However, several retrospective studies have shown that patients undergoing CABG before non-cardiac surgery have the same peri-operative mortality as patients who have no clinical signs of CAD.^{30–32} The largest study assessed 3368 patients with known CAD undergoing non-cardiac surgery being assigned either to medical therapy or CABG in the Coronary Artery Surgery Study (CASS).³³ The patients who underwent CABG before their non-cardiac surgery had a peri-operative mortality rate of 1.7% compared to 3.3% in patients who received medical therapy.

Foster *et al.*³⁴ conducted a retrospective analysis of 1600 patients from the CASS registry who eventually underwent major vascular surgery. This study revealed significant differences in mortality between patients who underwent pre-operative CABG (0.9%) and those who had not (2.4%). However, there also was a 2.3% mortality rate associated with CABG. In patients in whom coronary revascularization is

indicated, timing of the procedure depends on the urgency of the vascular surgical procedure balanced against the stability of the CAD. Patients undergoing elective major vascular surgery who are found to have high risk coronary disease and whom long-term outcome would be improved by CABG, should generally undergo revascularization before there elective surgery.⁵

Discussion

Cardiac complications are the leading cause of morbidity and death in patients undergoing vascular surgery.¹ Several studies have shown that patient's undergoing major vascular surgery have an increased risk of peri-operative cardiac complications, compared to patient's who have other types of non-cardiac surgery.^{3,4} This phenomenon is most likely explained by the known association between coronary disease and peripheral vascular disease.

Roughly 10% of patients will be considered to be at high risk for cardiac complications after clinical evaluation.³⁵ Among unselected patients undergoing vascular surgery, an additional 9–20% may be reclassified as high risk by non-invasive testing.³⁶ In most ambulatory patients, the test of choice is exercise electrocardiography, which provides both an estimate of functional capacity and can detect myocardial ischemia. In patients with either uninterpretable or major abnormalities on ECG, or patients who cannot meet the physical requirements of the exercise portion of the exam, should undergo stress echocardiography or SPECT.⁵ Patients with evidence of stress induced myocardial ischemia on non-invasive testing have an 8–38% risk of cardiac death or MI within 30 days after surgery.^{25,36} In contrast, in patients without evidence of stress induced myocardial ischemia on non-invasive testing, have cardiac complication rates the range of 0–5%.²⁵ Previously mentioned studies have proven that the use of peri-operative beta-blockade reduces the incidence of cardiac complications post-operatively in all patients undergoing major vascular surgery.

For the small percentage of patients who are at high risk and have symptoms of unstable angina or residual ischemia after recent MI pre-operatively, it may be appropriate to proceed directly to coronary angiography rather than perform a non-invasive study.⁵ Coronary revascularization via PTCA or CABG should only be performed in patients who meet the criteria for the respective procedures independent of the proposed vascular surgery procedure. The benefit of prophylactic coronary revascularization

has never been proven in a randomized prospective clinical trial.

Conclusion

When a surgeon is evaluating a patient for major vascular surgery the first step is to risk stratify the patient

based on history and physical examination (Fig. 1). If a patient is determined to be low risk then no non-invasive testing is needed, but peri-operative beta-blockade should be started in the absence of contraindications. However, if a patient is determined to be at intermediate or high risk for a peri-operative cardiac complication then non-invasive cardiac testing

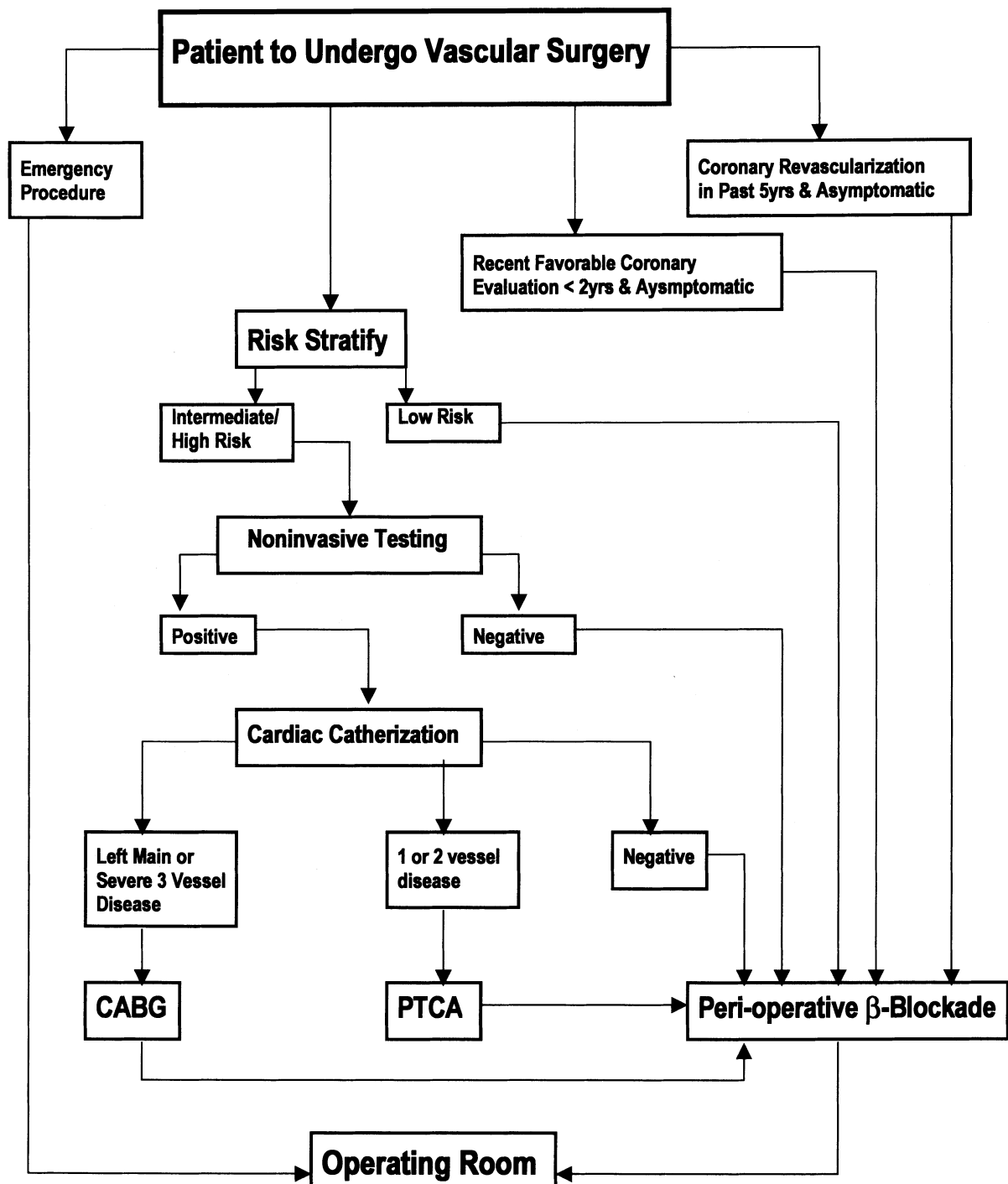


Fig. 1. Algorithm for cardiac evaluation and management of vascular patients.

should be the next step. If this test is negative, then the patient may proceed to surgery with peri-operative beta-blockade. On the other hand, if the test is positive then the patient should undergo cardiac catheterization. A patient with a negative cardiac catheterization should undergo surgery with peri-operative beta-blockade. If it is found that the patient has one or two vessel disease then PTCA should be performed followed by surgery with peri-operative beta-blockade. Lastly, in patients with left main coronary artery or severe three vessel disease should have a CABG followed by surgery with peri-operative beta-blockade.

With the increased patency rates for coronary artery stents in patients with significant coronary artery disease, the AHA/ACC may have to re-evaluate their guidelines/recommendations for the time period of re-testing a patient who has already undergone coronary revascularization. Currently, the AHA/ACC guidelines state that a patient who has had coronary revascularization within the last 5 years and is asymptomatic needs no further diagnostic testing before surgery. However, the recent advent of endoluminal brachytherapy, gene therapy, and pharmacologically coated stents (i.e. actinomycin D, taxol, and sirolimus) aimed at reducing intimal hyperplasia in blood vessels, and hence increasing stent patency rates may increase the time period before cardiac testing is necessary after coronary revascularization.

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